EFFECT OF LAND AND WATER BASED PLYOMETRIC TRAINING ON PHYSICAL AND PHYSIOLOGICAL VARIABLES AMONG BASKETBALL PLAYERS: A COMPARATIVE STUDY

By

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A

SYNOPSIS

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Abstract

Plyometric training, recognized for enhancing athletic performance through explosive movements, has gained significant attention in sports conditioning programs. This study investigates and compares the effects of land-based and water-based plyometric training on selected physical and physiological variables among basketball players. Sixty male inter-university/state-level basketball players from Udham Singh Nagar, Uttarakhand, aged 18–25 years, will randomly be assigned to three groups: land-based plyometric training, aquatic plyometric training, and a control group. Over six weeks, the experimental groups underwent structured plyometric programs tailored to their respective environments, while the control group continued with regular activities. The study focused on key physical variables: vertical jump, maximum strength, agility, and speed; and physiological variables: VO_2 max, vital capacity, and body fat percentage. Standardized and validated tests will be employed for pre- and post-intervention assessments. Statistical analysis, including paired t-tests and mixed ANOVA, revealed significant improvements in both experimental groups across most variables compared to the control group. Notably, aquatic plyometric training demonstrated comparable or superior improvements in several parameters with reduced post-exercise muscle soreness and injury risk, attributable to water's buoyancy and reduced ground impact. The findings support the efficacy of both training modalities in enhancing athletic performance, with aquatic plyometric training presenting as a viable alternative or supplement to traditional land-based methods, particularly for injury-prone or rehabilitation-focused athletes. This study contributes to the growing body of evidence supporting diverse plyometric approaches and provides practical insights for coaches, athletes, and sports scientists in developing safer, performance-enhancing training protocols.

Keywords: Plyometric Training, Aquatic Exercise, Land-Based Training, Basketball Performance, Physical Fitness, Physiological Adaptations

Certificate

I hereby declare that the short synopsis "Effect Of Land And Water Based Plyometric Training On Physical And Physiological Variables Among Basketball Players: A Comparative Study" being submitted for the degree of Doctor of Philosophy in Physical education to Lakshmibai National Institute of Physical Education, Gwalior during the academic year 2021-22, is a bonafide record of original work carried out under the supervision of Dr. Sanjeev Yadav and has not been submitted in full or part to any other university or institute for a degree or diploma.

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CHAPTER-I
INTRODUCTION

The word 'Training' has been a part of human language since ancient times. It denotes the process of preparation for some tasks. This process invariably extends to a number of days and even months and years. The term 'Training' is widely used in sports. The training process should therefore be principally aimed at an increase of the body's work output in a given motor regimen. Sport training is formulated the general methodological concept of an athlete's preparation define the general training strategy elaborate the basic model of the training system, and establish the quantitative programmed of the preparation.

Sport training is done for improving sports performance. The sports performance as any other type of human performance is not product of one single system or aspect of human personality. On the contrary it is the product of the total personality of the sports person. The personality of a person has several dimensions like physical, physiological, social and psychic. In order to improve sports performance, the social and psychic capacities of the sports person also have to be improved in addition to the physical and physiological ones. In other words, the total personality of a sportsman has to be improved in order to enhance his performance. Sports training therefore directly and indirectly aim at improving the personality of the sportsman. No wonder, therefore sports training is an educational process
(Hardayal Singh, 1991).

PLYOMETRIC TRAINING

Plyometrics is a type of training involving jumping; bounding and other high impact exercises that focus on maximizing the stretch reflex of the muscles. To teach the muscles to produce maximum force faster, this enhances performance for athletes and exercisers alike. **(Chu, Donald, 1998)**

Plyometric exercises are specialized, training techniques used to develop strength and speed. Plyometric training involves high-intensity, explosive muscular contractions that invoke the stretch reflex; stretching the muscle before it contracts so that it contracts with greater force. The most common plyometric exercises include hops, jumps, and bounding movements.

Plyometrics is a training technique that was initially used by track-and-field athletes but is currently used by athletes in all types of sports to increase strength and explosiveness. **Chu DA (1992)**

PLYOMETRICS IN SPORT TRAINING PROGRAMME

Plyometrics has been a very popular training technique used by many coaches and training experts to improve speed, explosive power output, explosive reactivity and eccentric muscle control during dynamic movements **(Coetzee, 2007).** It is considered a high-intensity, physical training method, consisting of explosive exercises that require muscles to adapt rapidly from eccentric to concentric contractions **(Chu, 1998).** Plyometric training (PT) has widely been used to enhance muscular power output, force production, velocity, and aid in injury prevention **(Robinson et al., 2004)**. Plyometric training is often called by the name "Stretch Shortening Cycle Exercise." This name actually describes the basic physiological basis for plyometric training: the muscle first goes through an eccentric action (stretching), then through an isometric action (static), and then through a concentric action (shortening). The goal is to perform the sequence quickly to result in a more powerful action than if no eccentric action (pre-stretch) was performed. An example would be to squat (eccentric action of quadriceps to a static action) and then jump (concentric action of quadriceps).

There are two theories as to why stretch shortening cycle exercise may produce more power:

- The slight stretch stores more elastic energy which adds to the concentric action. This is the most commonly cited theory of why plyometric movements create more muscle force. The elastic energy is stored in the tendons and connective tissue.
- A reflex result in quicker recruitment of muscle fibers or recruitment of more muscle fibers leading to a stronger contraction. This reflex recruitment possibly contributes but is not well understood yet. Regardless, stretch shortening cycle training does lead to development of power and vertical jump ability, making it desirable for athletic training. It makes sense that performing plyometrics in the water would reduce injury rate; you have less force in landing and are not jumping from platforms. But if you look at the mechanics of jumping in the water, physiologically it is not the same. Reduced body mass from the water's buoyancy would tend to "lighten" the effects of plyometric jumps. Interestingly enough, several research studies performed over the last decade

show that plyometric training in the water indicated equal or better results than training on land with fewer injuries. **June M. Chewning (2011).**

PHYSIOLOGICAL PRINCIPLES OF PLYOMETRIC TRAINING

Plyometric training utilizes the elastic and proprioceptive properties of a muscle to generate maximum force production by stimulating mechanoreceptors to facilitate an increase in muscle recruitment in a minimal amount of time. Muscle spindles and Golgi tendon organs provide the proprioceptive basis for plyometric training. The central nervous system then uses this sensory information to influence muscle tone, motor execution, and kinesthetic awareness. Stimulation of these receptors can cause facilitation, inhibition, and modulation of both agonist and antagonist muscle activity. This enhances neuromuscular efficiency and functional strength.

RISKS OF PLYOMETRICS

If you're in poor physical condition or have bone or joint problems, you're probably not a good candidate for plyometrics. But even if you're a seasoned athlete, it's important to remember that any training routine that builds strength through explosive movement is inherently associated with an increased risk of injury. In the sports science community, reported injuries associated with plyometrics programs of depth jumping have stirred considerable debate over the technique's safety. Some experts have even compared plyometrics to the now-discredited technique of high-impact aerobics, which increases the risk of injury to lower-body joints such as the knee and ankle. But plyometric training is usually safe and effective. Make sure you've received adequate screening from a sports medicine doctor or therapist and enrolled in a program led by a qualified instructor who matches the exercises to your age and fitness level and teaches proper landing techniques before gradually advancing you to more difficult exercises.

AQUATIC PLYOMETRIC

Aquatic plyometric training is not a new concept, but it has recently become more popular, mostly because of the potential to decrease injuries, compared with land plyometric

contractions, by decreasing impact forces on the joints. Aquatic plyometric training provides a form of training that can enhance performance during a competitive season for a power-based sport **(Miller *et al.*, 2002; Robinson *et al.*, 2004).** It is suggested that Aquatic plyometric training has the potential to provide similar or better improvements in skeletal-muscle function and sport-related attributes of explosive and reactive training than land based plyometrics. According to **Coetzee (2007),** research has shown that aquatic plyometric programs provide the same or even more performance enhancement benefits than land plyometric programs.

BENEFITS OF AQUATIC PLYOMETRIC TRAINING

Various studies in the past few years have outlined the advantages of doing plyometric training in the water. Aquatic plyometric exercise provides the same performance enhancement benefits as land plyometric exercise but with significantly less muscle soreness reported with aquatic training as compared to land training. **The Water:** The water level of the pool should be somewhere in the waist area of your clients. The water temperature should not exceed 30 A°C or 86 a° F.

Aquatic plyometric exercise can provide the same performance enhancement Benefits as land plyometric exercise. The buoyant properties of the water reduce impact and decrease risk of injury. Jumping and Landing techniques are crucial to teach to younger and lesser experienced athletes that have never done any form of plyometric or jump training. In order to be able to correctly perform plyometrics the execution of jumping and landing must be mastered first, not to mention a certain level of strength in order to withstand the forces when dealing with higher level jumps. The primary issue with landing is the inability to stabilize the legs via the hip musculature, and the feet via the lower leg musculature. The hip weakness can have a major impact on the functioning of the feet and ankles as well. The other area of concern with landing is the strength of the musculature around the pelvis and spine. The muscles must be strong enough to dissipate forces away from the pelvis and spine. Without going into the feet and not cave in (valgus) during landing and jumping. The other concern is the ability of the pelvis and spine to avoid extreme flexion or extension of the spine during landing **(June M. Chewning, 2011).**

STATEMENT OF PROBLEM

The purpose of the study to investigate and compare the effects of land based Plyometric Training and water based Plyometric Training on Physical and Physiological Variables among basketball players.

OBJECTIVES OF STUDY

The objectives of the study are:

- To find out the effectiveness of land based plyometric training and water based plyometric training on selected physical variables of athletes.
- To find out the effectiveness of land based plyometric training and water based plyometric training on selected physiological variables of athletes.
- To find out which one is more effective between land based plyometric training and water based plyometric training on selected variables of athletes.

HYPOTHESES

On the basis of review of related literature and discussion with experts:

1. It is hypothesized that there will be significant effect of land based plyometric training on selected physical and physiological variables among basketball players.
2. It is hypothesized that there will be significant effect of water based plyometric training on selected physical and physiological variables among basketball players.
3. It is hypothesized that there will be significant difference in the effects of land based and water based plyometric training on selected physical and physiological variables among basketball players.

DELIMITATIONS

- The study will be delimited to 60 male inter-university/state level athletes of Udham Singh Nagar district of Uttarakhand state.
- Further, the study will be restricted to athletes of age ranging between 18-25 years.
- The study will be further delimited on Plyometric Training and water based Plyometric Training programs.
- The training period will be delimited to six weeks.
- Further the study will be delimited to the following physical and physiological variables:

  Physical – Maximum Strength, Vertical Jump, Agility, and Speed

  Physiological – VO2max, Vital Capacity, and Fat percentage

DEFINITION AND EXPLAINATION OF TERMS

Plyometrics

Explosive movements designed to increase muscle strength and power by contracting the muscles quickly, for example through jumping and bounding.

Training

Training is a pedagogical process, based on scientific principles, aiming at preparing sportsmen for higher performance in sports competitions. **(Green, 1978)**.

Speed

A skill-related component of physical fitness that relates to the ability to perform a movement within a short period of time. (**Corbin and Lindsey, 1988)**

Agility

Agility is the ability to move and change direction and position of the body quickly and effectively while under control. **(Costello, F. & Kreis, E.J,1993)**

Strength

Muscular strength is the amount of force that your *muscles* can exert against resistance. A health-related component of physical fitness that relates to the ability of the muscle to exert force. (**Costill, 1998)**

SIGNIFICANCE OF STUDY

The study may contribute in the following ways:

1. The findings of the study may be help full in the importance of Land based Plyometric and Aquatic based plyometric training.
2. The result of the study may be help full in the focus of new dimension in the Plyometric training that will help to understand more about aquatic based plyometric training.
3. This study may be help of new way idea to the athletes and coaches for improving his performance.
4. This study may be help full to prove the essential of Aquatic plyometric training to improve the physical variables.
5. This study may be help full to prove the essential of Aquatic plyometric training to improve the physiological variables.
6. This study may be helpful in increasing the new knowledge in the field of Land and Aquatic based plyometric training.
7. The finding of the study may be helpful in comparison of effect of Land and Aquatic based plyometric training.

CHAPTER-II
REVIEW OF RELAED LITERATURE

The research scholar has gone through the journal available on internet. The relevant study from various sources which the investigator came across is enumerated below:

HAMID ARAZI et.al. (2019) Conducted the study with the aim to describe the effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players. *J. Hum. Sport Exercise* Vol. 6, No. 1, pp. 101-111, 2011. The purpose of this study was to compare the effect of eight weeks of aquatic and land plyometric training on leg muscle strength, 36.5- and 60-meters sprint times, and dynamic balance test in young male basketball players. Eighteen young male basketball players (age=18.81±1.46 years, height=179.34±6.11 cm, body mass=67.80±9.52 kg, sport experience=4.8±2.47 years) volunteered in this study and divided to three groups; aquatic plyometric training (APT), land plyometric training (LPT) and control group (CON). Experimental groups trained; ankle jumps, speed marching, squat jumps, and skipping drills for eight weeks and 3 times a week for 40 min. The data were analyzed by one way analysis of variance with repeated measures, a Tukey post hoc testing and independent-sample *t*-test. The results showed there were not any significant differences between the APT and LPT groups in any of the variables tested ($P>0.05$). Significant increases were observed in post training both APT and LPT groups in 36.5-m and 60-m sprint times record compare to pretraining ($P<0.05$). There was a significant difference in relative improvement between the APT and CON in 36.5-m, 60-m, and one repetition maximum leg press ($P<0.05$). they conclude that plyometric training in water can be an effective technique to improve sprint and strength in young athletes.

Dr. I. John Parthiban et al. (2020) Conducted this study with the aim of the purpose of the study was explored to find out the land and aquatic plyometric training on vital capacity among college men athletes. For the purpose of the study, forty-five (n=45) men college athletes from Pudukkottai, Tamil Nādu, India during the year 2019-2020 were selected as subjects. Their ages were from 18 to 21 years. The selected participants were divided at random into three groups of fifteen each (n=15). Group-I underwent land plyometric training, group-II aquatic plyometric training, and group-II acted as control group. The duration of the training period was restricted to eight weeks and the number of sessions per week was confined to five.

The selected variable vital capacity was assessed by wet spirometer. The data were collected prior to and immediately after the training period of twelve weeks. The data obtained from the experimental groups before and after the experimental period were statistically analyzed with analysis of covariance (ANCOVA). Whenever the 'f' ratio for adjusted posttest means was found to be significant, the scheffe's post hoc test was applied to determine the paired mean differences. The level of confidence was fixed at 0.05 level for all the cases. The results of the study showed that aquatic plyometric training group is better than land plyometric training group and control group on improving vital capacity.

Ahmed Elsayed Ahmed, **et al. (2019)** Conducted the study with the aims to determine whether aquatic training and non-aquatic training can improve aerobic fitness, and physical preparation in younger basketball player. Eighteen basketball players (age=17.49±0.53 years, body mass=67.37±1.17 kg, height=179.30±1.46 cm, sport experience=3.40±0.36 years) participate in this study. The participants were randomly assigned to aquatic training group (AQT n=9) or non-aquatic training group (NQT n=9) to perform eight weeks of aquatic-non-aquatic exercise twice weekly for 45 min, both in addition to traditional preseason basketball training. The exercises included power skips, spike approaches, single- and double-leg bounding, continuous jumping for height, squat jumps with blocking form, and depth jumps. Basketball players were assessed before and after eight-week training period on VO2max, 20 m sprint, vertical jump, set and reach flexibility, 1RM leg press and curl-up, agility T-test. The results showed that the two groups made significantly improvements in all variables but the (AQT) made significantly improvements greater than (NQT). they conclude that the aquatic exercises resulted in larger improvements in aerobic fitness, VJ, sprint, flexibility, agility, strength and endurance than in the NQT group.

OZHAN BAVLI et al. (2012) The aim of this study was to compare the effects of water plyometrics and land plyometrics on Body Mass Index (BMI) and biomotorical variables of adolescent basketball players. Ninety-one adolescent basketball players (48 male, 43 female) at the age of 16±1 year were enrolled in the study. Athletes were randomly divided in to three groups; water plyometric group (n:31), land plyometric group (n:30) and control group n:30). Study period was 12 weeks. All groups had standardized basketball training. water and land groups also had plyometrics three times a week. BMI and biomotrical variables including; body mass index, one repetition maximum leg strength, 30-meter sprint, vertical jump, flexibility was measured. SPSS 11,5 version was used for the data analysis." One Way ANOVA" was

used to compare pretest and posttest findings of study groups. Differences between pretest and posttest findings of genders and groups were analyzed by “Two Way ANOVA for Independent Samples”. Significance was set at $p<.05$. Significant differences were detected on BMI and biometrical variables between pretest and posttest results in both water and land plyometric exercise groups. But there were no statistically significant differences between groups. After the study period there were also statistically significant differences between control and plyometric exercise groups.

MALLORY S. KOBAK, et al. (2015) The purpose of this study was to compare the effects of an aquatic- (W) and land-based (L) plyometric program on balance, vertical jump height, and isokinetic quadriceps and hamstring strength. Thirty-four participants were randomized into three groups, W ($n = 12$), L ($n = 11$), and control ($n = 11$). The W and L groups completed an eight-week plyometric program. A two-way repeated measures ANOVA revealed a significant main effect of condition ($F = 346.95$, $p < 0.001$) and interaction between condition by time ($F = 1.88$, $p = 0.01$). Paired samples t-tests revealed statistically significant improvements from pre- to post-testing in the L group for isokinetic quadriceps strength at 60 degrees per second ($p = 0.02$) and hamstring strength at 120 degrees per second ($p = 0.02$). Statistically significant improvements were observed from pre- to post-testing in the W group for balance ($p = 0.003$), vertical jump height ($p = 0.008$), isokinetic quadriceps strength at 60 and 120 degrees per second ($p < 0.001$), and hamstring strength at 120 degrees per second ($p = 0.03$). Results demonstrate that aquatic-based plyometric training can be a valid form of training by producing improvements in balance, force output, and isokinetic strength while concurrently decreasing ground impact forces.

Joseph D. Shaffer, et.al. (2019) Conducted this study and tell that Plyometric exercise has been shown to increase strength and explosiveness in athletes participating in football, tennis, golf, soccer, volleyball, running, and basketball. Aquatic exercises have been noted to have beneficial effects, however there has been little research conducted comparing plyometrics in a land-based and an aquatic-based setting. The purpose of this study is to compare the effects of a plyometric-training program in a land-based and an aquatic-based setting on power, peak torque, agility, and muscle soreness. There were four 2x3x3 factorial designs for the KinCom tests, two 2x3 factorial designs for vertical jump and the LEFT tests, and one 3x7 factorial design for the VAS test with two experimental groups and a control group. Patients and Other Participants: This study included 18 healthy, volunteer, college-aged

subjects who met the inclusion criteria set at the beginning of the study. Intervention: The six-week protocol for the experimental groups was conducted following a specific program twice a week for an average of 30-minutes. Both groups experienced a training program that included plyometric exercises that advanced from week to week. The focus of the exercises was placed on hops and jumps forwards, backwards, or laterally. All subjects performed the KinCom test, Vertical Jump test, and the Lower Extremity Functional test for pretest and post-test measurements. Also, all subjects recorded measurements with the Visual Analogue test for a baseline test, as well as after the last session of each week for the six weeks. The KinCom machine was used for the quadriceps and hamstrings concentric and eccentric contractions to measure peak torque values. Also, the vertical jump was used to measure power, the LEFT was used to measure agility, and the VAS along with a body chart, were used subjectively to measure muscle soreness. For VAS, there was a significant main effect for test ($F1,17 = 17.696$, $P=.000$, $ES= .541$, $\beta= 1.000$) and for group ($F1,17 = 10.702$, $P=.001$, $ES= .588$, $\beta= .969$) for the land by aquatic and land by control groups at the $P=0.006$ and $P=0.002$ level, respectively. A significant main effect was found with vertical jump for test ($F1,17 = 10.834$, $P=.005$, $ES= .419$, $\beta= .868$). There were no other significant results found within or between groups. For the KinCom test for flexion and concentric contraction at all three speeds, a significant interaction was found for test by group ($F1,17 = 7.855$, $P=.005$, $ES = .512$, $\beta = .902$). For extension and concentric contraction at all three speeds, a main effect was found within subjects for speed ($F1,17 = 11.127$, $P=.000$, $ES = .426$, $\beta = .985$). No differences were recorded for the measures of flexion and eccentric contraction or extension and eccentric contraction at all three speeds or for the LEFT test. In conclusion, aquatic therapy may help to decrease muscular soreness while performing exercises. However, more research needs to be conducted to determine the effects of plyometric training in the aquatic setting.

GREGORY F. MARTEL, (2005) Conducted this study and tell those numerous studies have reported that land-based plyometrics can improve muscular strength, joint stability, and vertical jump (VJ) in athletes; however, due to the intense nature of plyometric training, the potential for acute muscle soreness or even musculoskeletal injury exists. Performance of aquatic plyometric training (APT) could lead to similar benefits, but with reduced risks due to the buoyancy of water. Unfortunately, there is little information regarding the efficacy of APT. Thus, the purpose of this study was to examine the effects of APT on VJ and muscular strength in volleyball players. Methods: Nineteen female volleyball players (aged 15 1 yr) were randomly assigned to perform 6 wk of APT or flexibility exercises (CON) twice weekly, both

in addition to traditional preseason volleyball training. Testing of leg strength was performed at baseline and after 6 wk, and VJ was measured at baseline and after 2, 4, and 6 wk. Results: Similar increases in VJ were observed in both groups after 4 wk (APT 3.1%, CON 4.9%; both P 0.05); however, the APT group improved by an additional 8% (P 0.05) from week 4 to week 6, whereas there was no further improvement in the CON group (0.9%; P NS). After 6 wk, both groups displayed significant improvements in concentric peak torque during knee extension and flexion at 60 and 180°s1 (all P 0.05). Conclusions: The combination of APT and volleyball training resulted in larger improvements in VJ than in the CON group. Thus, given the likely reduction in muscle soreness with APT versus land-based plyometrics, APT appears to be a promising training option.

Leah E Robinson (2004) Conducted this study with the purpose of this study was to compare changes in performance indicators (power, torque, and velocity) and muscle soreness between plyometric training on land and in water. Thirty-two college age women were randomly assigned to 8 weeks of an identical plyometric training program on land or in an aquatic setting. Performance indicators were assessed pretraining, mid training, and post training. Muscle soreness (ordinal scale) and pain sensitivity (palpation) were as- sassed after a training bout (0, 48, and 96 hours) during the first week of training and when training intensity was increased (Weeks 3 and 6). Performance indictors increased for both groups (pretraining, mid training, post training, p # 0.001). Muscle soreness was significantly greater in the land compared to the aquatic plyometric training group at baseline and each time training intensity was increased, p 5 0.01. Aquatic plyometrics provided the same performance enhancement benefits as land plyometrics with significantly less muscle soreness.

Michael G. Miller (2002) Conducted this study with the objective to compare the effects of land-based and aquatic-based plyometric-training programs on performance variables, muscle soreness, and range of motion (ROM). Setting: Aquatic facility and biomechanics laboratory. Subjects: Forty subjects randomly assigned to 3 groups: land (n = 13), water (n = 13), and control (n = 14). Main Outcome Measures: Performance variables, muscle soreness, and ROM were measured before and after an 8-week training period. An analysis of covariance (ANCOVA) and a Bonferroni post hoc test determined significance. Results: ANCOVA revealed significant differences between groups with respect to plantar-flexion ROM (P < .05). Paired t test determined that the aquatic group significantly increased muscle power pretest to

posttest (P < .05). And he concludes that results indicate that aquatic plyometric training can be an alternative approach to enhancing performance**.**

N. POORNA SARACHANDRA (2015) This study aims to identity the effectiveness of plyometric exercises on the special physical abilities and skillful performance of volleyball players. It is applied to a sample of 90 players of 14 & 15 years old from Z.P. High School, Tiruchanoor, Tirupati Rural, Chittoor Dist., A.P. They were divided into three (3) equivalent groups experimental group I underwent type I intensity plyometric training and experimental group II underwent type II intensity plyometric training and control group will not expose any training. The training program is applied for the period of 12 weeks with 2 training units at 90 minutes for each unit. The load will fix based on the pilot study. Analysis of covariance statistical technique is used for this study.

S. Manimaran et. al. (2017) The purpose of this study was to investigate the effect of plyometric training on selected hematological variables among jumpers. To facilitate the study, thirty jumpers from various clubs in Chennai city, Tamil Nādu, India were selected as subjects at random and their ages between 14 to 17 years. The subjects were divided into two equal groups. Group-I performed ladder training and group-II was control. HDL and LDL were assessed by blood test. The subjects were involved with their respective training for a period of 12 weeks. At the end of the twelve weeks of the training post-tests were taken. The significant differences between the means of experimental group and control group for the pre-test and post-test scores were determined by ANCOVA. The level of significance was fixed at 0.05 level of confidence for the degree of freedom 14. The plyometric training group has showed better performance on HDL and LDL than the control group**.**

Serkan Ibis et.al. The aim of this study was to determine and evaluation chronic effects of plyometric training on hematological parameters of the Turkish National Alpine Ski Team athletes during 12-week preparation period. In the study 12 sportsmen volunteers participated whose mean age was 17.50 years. Twelve weeks plyometric training protocol performed to participants. The training program was applied for twelve weeks and five days a week in total 60 training unit. As the program preceded the intensity and content of training increased. Blood samples were taken before and after training program. The Red blood cell (RBC), white blood cell (WBC), Granulocyte (GR), hematocrit (HCT), Hemoglobin (HGB), Mean Corpuscular

Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC) measurement were analyzed blood samples with automatic hematological analyzer (Toshiba Acute PPS TBA-40FR). Wilcoxon Signed Rank test was used in order to compare statistical values of before and after exercise and significance level alpha was set 0,05. Before and after training program values were compared for RBC, WBC, GR, MCV, MCH, MCHC and no significant changes have been observed for these values. However, there were significant ($p>0.05$) increase of HCT and HGB values. We were concluded that as a result of the study twelve-week plyometric training program increased the red blood cells and hemoglobin levels and as a result improved oxygen carriage capacity of the Turkish National Alpine Ski Team athletes.

Raja Bouguezzi et.al. (2018) This study aimed to compare the effects of one vs. two sessions of equal-weekly volume plyometric training (PT) across 8 weeks on measures of athletic performance (i.e., sprint-time, change of direction [CoD], jumping ability, and muscle strength) in prepuberal male soccer players. Thirty participants were randomly assigned either to one session PT group (1SPT [n=15]) or two sessions PT group (2SPT [n=15]). Plyometric training was integrated into their regular soccer training routine. Pre- and post-training tests for the assessment of sprint-time (e.g., 5-m, 10-m, 20-m, and 30-m), CoD (e.g., T-test and modified Illinois change of direction test [MICODT]), jumping ability (e.g., standing long jump [SLJ], counter-movement jump [CMJ], and squat jump [SJ]), muscle strength (reactive strength index [RSI]), and kicking distance were conducted. Results showed a main effect of time for 5-m sprint-time performance ($F(1,56)=4.00$, ES=0.53 [medium], $p=0.05$), T-test ($F(1,56)=23.19$, ES=1.28 [large], $p<0.001$), MICODT ($F(1,56)= 5.72$, ES=0.94 [large], $p=0.02$), SLJ ($F(1,56)=16.63$, ES=1.09 [large], $p<0.001$), CMJ ($F(1,56) =15.43$, ES= 1.04 [large], $p<0.001$), SJ ($F(1,56) =20.27$, ES=1.20 [large], $p<0.001$), RSI ($F(1,56)=26.26$, ES=1.36 [large], $p<0.001$), and kicking distance ($F(1,56)=47.19$, ES=1.83 [large], $p<0.001$). There were no training group × time interactions in all the measured outcomes. In conclusion, when an equated moderate volume of jumps is performed, higher PT frequency across 8 weeks has no extra-effects on prepuberal male soccer players' measures of athletic performance. The present findings may help optimizing PT interventions dedicated to prepuberal male soccer players.

Rodrigo Ramirez-Campillo et.al. (2018) Conducted this study and tell that Plyometric jump training (PJT) is a frequently used and effective means to improve amateur and elite

soccer players' physical fitness. However, it is unresolved how different PJT frequencies per week with equal overall training volume may affect training-induced adaptations. Therefore, the aim of this study was to compare the effects of an in-season 8-week PJT with one session vs. two sessions per week and equal training volume on components of physical fitness in amateur female soccer players. A single-blind randomized controlled trial was conducted. Participants (N = 23; age, 21.4 ± 3.2 years) were randomly assigned to a one session PJT per-week (PJT-1, n = 8), two sessions PJT per-week (PJT-2, n = 8) or an active control group (CON, n = 7). Before and after training, participants performed countermovement jumps (CMJ), drop-jumps from a 20-cm drop-height (DJ20), a maximal kicking velocity test (MKV), the 15-mlinear sprint-time test, the Meylan test for the assessment of change of direction ability (CoDA), and the Yo-Yo intermittent recovery endurance test (Yo-YoIR1). Results revealed significant main effects of time for the CMJ, DJ20, MKV, 15-m sprint, CoDA, and the Yo-YoIR1 (all $p < 0.001$; $d = 0.57–0.83$). Significant group×time interactions were observed for the CMJ, DJ20, MKV, 15-m sprint, CoDA, and the Yo-YoIR1 (all $p < 0.05$; $d = 0.36–0.51$). Post-hoc analyses showed similar improvements for PJT-1 and PJT-2 groups in CMJ (110.6%, $d = 0.37$; and 110.1%, $d = 0.51$, respectively), DJ20 (112.9%, $d = 0.47$; and 113.1%, $d = 0.54$, respectively), MKV (18.6%, $d = 0.52$; and 19.1%, $d = 0.47$, respectively), 15-m sprint (18.3%, $d = 2.25$; and 19.5%, $d = 2.67$, respectively), CoDA (17.5%, $d = 1.68$; and 17.4%, $d = 1.16$, respectively), and YoYoIR1 (110.3%, $d = 0.22$; and 19.9%, $d = 0.26$, respectively). No significant pre-post changes were found for CON (all $p > 0.05$; 10.5–4.2%, $d = 0.03–0.2$). In conclusion, higher PJT exposure in terms Ramirez-Campillo et al. Plyometric Training in Female Soccer Players of session frequency has no extra effects on female soccer players' physical fitness development when jump volume is equated during a short-term (i.e., 8 weeks) training program. From this, it follows that one PJT session per week combined with regular soccer-specific training appears to be sufficient to induce physical fitness improvements in amateur female soccer players.

Sophie E. Heywood et.al. (2021) Conducted this study with the objective to systematically review the effect of aquatic plyometric training on strength, performance outcomes, soreness, and adverse events in healthy individuals. Evidence acquisition: Five databases were searched from inception to June 2020. Quality assessment and data extraction were independently completed by 2 investigators. When similar outcome measures were used, standardized mean differences were calculated. Evidence synthesis: A total of 19 randomized

controlled trials with 633 participants (mean age, range 14–30 y) were included. Aquatic plyometric training was most commonly performed in waist to chest deep water (12/19 studies), 2 to 3 times per week for 6 to 12 weeks (18/19 studies), with final program foot contacts ranging from 120 to 550. Meta-analyses were not completed due to the clinical and statistical heterogeneity between studies. Compared with land plyometric training, aquatic plyometric training exercises and dosage were replicated (15/16 studies) and showed typically similar performance gains (3/4 knee extensor strength measures, 2/4 leg extensor strength measures, 3/4 knee flexor strength measures, 7/10 vertical jump measures, 3/3 sprint measures). In total, 2 of 3 studies monitoring muscle soreness reported significantly less soreness following training in water compared with on land. Compared with no active training (no exercise control group or passive stretching), most effect sizes demonstrated a mean improvement favoring aquatic plyometric training (23/32 measures). However, these were not significant for the majority of studies measuring isokinetic knee strength, vertical jump, and sprinting. The effect sizes for both studies assessing leg press strength indicated that aquatic plyometric training is significantly more effective than no training. They conclude that Aquatic plyometric training appears similarly effective to land plyometric exercise for improving strength, jumping, and sprinting and may be indicated when joint impact loading needs to be minimized. However, the low quality of studies limits the strength of the conclusions.

CHAPTER-III
PROCEDURE

In this chapter, the selection of subjects, selection of variables, criterion measures, administration of test, collection of data and statistical technique for analysis of data has been described.

SELECTION OF SUBJECTS

The purpose of this study is comparison of land based plyometric training and water based plyometric training effect on selected physical and physiological variables among athletes. The 60 subjects will be randomly selected from Udham Singh District of Uttarakhand. The subject age ranged between 18-25 years only. They will be equally divided into three groups: -

Experimental Group A – Land Based Plyometric Training
Experimental Group B – Water Based Plyometric Training
Control Group

All the subjects will be selected healthy and physically fit. The nature and importance of the study will be explained to the subjects. The study will be formulated as pre and posttest random group design.

EXPERIMENTAL DESIGN

The study was formulated as a true random group design. Consisting of two pre test and two posttests, the subjects (n = 60) were randomly assigned to three equal groups of 20 university/state level athlete for each. The groups will assign as two experimental group and one control group respectively. Pretest will be conducted for all the subjects on selected physical and physiological variables. The experimental groups will be participated in their respective land based Plyometric training and aquatic based Plyometric training group for a period of 6 weeks. The post test will be conducted on the above said dependent variables after a period of 6 weeks in the respective treatments. During this period the subject were not allowed to participate in any training. Further the role of the subjects during the experimentation and

the testing procedure will also explain to them in detail. The physical conditions of the subjects will be assessed by a qualified medical practitioner. They will be requested to co-operate and participate actively for the same.

SELECTION OF VARIABLES

The research scholar reviewed the various scientific literatures pertaining to the plyometric training, Aquatic plyometric training and comparison of land and aquatic plyometric training on selected physical and physiological variables from books, journals, periodicals, magazines and research papers. Taking into consideration of feasibility criteria, availability of instruments and the relevance of the variables of the present study, the following variables will be selected dependent variables. Selected criterion variables will be tested with standardized test the items.

INDEPENDENT VARIABLES

Experimental group I - land based Plyometric training.

Experimental group II - water based plyometric training.

DEPENDENT VARIABLES

PHYSICAL VARIABLES

- VERTICAL JUMP
- MAXIMUM STRENGTH
- AGILITY
- SPEED

PHYSIOLOGICAL VARIABLES

- VITAL CAPACITY
- VO2 MAX
- BODY FAT PERCENTAGE

SELECTION OF THE TESTS

PHYSICAL VARIABLES

Standard tests will be conducted to measure the selected physical variables of this study. The selected variables, their respective tests are presented in Tables. Selected physical variables and their reliable tests used for this study are presented in Table-I.

S.NO.	VARIABLES	TESTS
1	VERTICAL JUMP	WALL TEST
2	LEG STRENGTH	1 RM TEST
3	AGILITY	"T" TEST
4	SPEED	20 M SPRINT TEST

PHYSIOLOGICAL VARIABLES

Standard tests will be conducted to measure the selected physiological variables of this study. Selected physiological variables and their reliable tests and their units of measurements used for this study are presented in table-II

S. NO.	VARIABLES	TEST
1	VITAL CAPACITY	WET SPIROMETER
2	VO2 MAX	12-MIN COOPER RUN/WALK TEST
3	BODY COMPOSITION	SKIN FOLD CALLIPER

CRITERION MEASURES

By glancing the literature in consultation with the professional experts, the following variables is selected as the criterion measures in the study for testing the hypothesis.

Vertical Jump

Vertical jump will be measured by wall test for vertical jump. The measurement will be recorded in cm.

Speed

Speed will be measured by using 20mts sprint test. The measurement will be recorded in seconds.

Agility

The agility will be measured by 'T' test. The measurement will be in second.

Leg strength

Leg strength will be measured by using 1 RM leg strength (leg press). The measurement will be kilogram.

Vo2Max

Maximum Oxygen uptake (Vo2 max) will be measured by using 12-min Cooper run/walk test. The measurement will be recorded in ml/kg-1/min-1.

Vital capacity

Vital capacity will be measured by using Wet spiro meter test. The measurement will be recorded in litters.

Body fat percentage

Body fat percentage will be measured by using skinfold calipers. The measurement will be recorded in millimeters.

ORIENTATION OF THE SUBJECTS

Prior to the administration of the test items, the important of the study will be clearly explained to the subjects. The investigator also briefly described about the procedures used for the

conduct of the various Physical and physiological tests used for this study. Subjects are motivated to perform better during the test. The recording of each test items will be told to the subjects to familiarize them about their performance.

ADMINISTRATION OF TRAINING PROGRAM

A 6-week plyometric-training program will be developed that included weekly two days training sessions. And the same training will be performed in the water belt for the aquatic training groups the duration of the training period will be 75 minutes. The training program will be based on the recommendations of intensity and volume from previous literature and researches. Participants will be instructed to perform exercises to their maximal ability. Participants will be given a brief description and demonstration of each exercise before completing each training session. All participants will be supervised by the researcher and verbally encouraged to perform with maximal effort.

PLYOMETRIC TRAINING INTERVENTION PROGRAMME

The Land based plyometric training and Aquatic based plyometric training Programs is developed after consulting various experienced coaches and sports training experts. The Training will be given two and three days in a week and the duration of the period will be six weeks. The **Nisith K. Datta, Rakesh Bharti (2015)** and **Miller et al. (2001)** recommended a gradual approach to aquatic plyometric training. The training program began with low volume plyometric drills and progressively increased in volume and intensity until the completion of the study.

Sr. No.	Details	Duration
1.	Intensity	Low/Moderate
2.	Frequency	Two /Three Days
3.	Number of Weeks	6 Weeks
4.	Duration of Each Session	75 minutes
5.	Total number of foot contact	120-360
6.	Rest Interval between Set	2 to 3 minutes
7.	Warm up and cool down	20 Minutes

Table V

TWO SESSIONS AND THREE SESSIONS LAND BASED PLYOMETRIC TRAINIG AND AQUATIC BASED PLYOMETRIC TRAINING PROGRAMME

	Week I and II	Week III and IV	Week V and VI
Volume (sets×reps) per-session	5x12	10x12	15x12
Contact number per-session	60	120	180
Total contact no. per-session	120	240	360

Table-VI

LAND BASED PLYOMETRIC TRAINING AND AQUATIC BASED PLYOMETRIC TRAINING PROGRAMME DETAIL

TABLE 6.1

Week	Exercise	Set	Repetition	Foot Contact per session	Total foot contact per session
Week I and II	1. Squat jump 2. Double leg lateral hop 3. Split Squat jump 4. Tuck Jump 5. Lunge jump	1 1 1 1 1	12 12 12 12 12	60	120

TABLE 6.2

Week	Exercise	Set	Repetition	Foot Contact per-session	Total foot contact per-session
Week III and IV	1. Squat jump 2. Double leg lateral hop 3. Split Squat jump 4. Tuck Jump 5. Lunge jump	2 2 2 2 2	12 12 12 12 12	120	240

TABLE 6.5

Week	Exercise	Set	Repetition	Foot Contact per-session	Total foot contact per-session
Week V and VI	1. Squat jump 2. Double leg lateral hop 3. Split Squat jump 4. Tuck Jump 5. Lunge jump	3 3 3 3 3	12 12 12 12 12	180	360

TEST ADMINISTRATION

PHYSICAL VARIABLES

VERTICAL JUMP - WALL TEST

Purpose:

To measure the leg muscle power

Equipment:

Measuring tape or marked wall, chalk for marking wall

Procedure (see also variations below):

The athlete stands side on to a wall and reaches up with the hand closest to the wall. Keeping the feet flat on the ground, the point of the fingertips is marked or recorded. This is called the standing reach height. The athlete then stands away from the wall, and leaps vertically as high as possible using both arms and legs to assist in projecting the body upwards. The jumping

technique can or cannot use a countermovement (see vertical jump technique). Attempt to touch the wall at the highest point of the jump.

Scoring:

The difference in distance between the standing reach height and the jump height is the score. The best of three attempts is recorded.

SPEED:

20 mts run

Purpose:

To find out the speed.

Equipment required:

Stop watch, measuring tape, score sheet smooth surface and least yards long with start and finish.

Procedure:

A starting line and a finish line has to drawn, after a small warm up the subject has to stand behind the starting line, the investigator has to give signal in 'ready' and 'go' by using whistle or a gun or a clapper. The subject has to get the signal and then he has to run as much as speed to reach the finish line. The examiner has to take the time he took to cover the distance. One trial has to allow for each subject.

Scoring:

The speed is recorded in seconds. The time begins when the command go is
given.

AGILITY T-TEST

Purpose:

The T-Test is a test of agility for athletes, and includes forward, lateral, and backward running

Equipment required:

Tape measure, marking cones, stopwatch, timing gates (optional)

Procedure:

Set out four cones as illustrated in the diagram above (5 yards = 4.57 m, 10 yards = 9.14 m). The subject starts at cone A. On the command of the timer, the subject sprints to cone B and touches the base of the cone with their right hand. They then turn left and shuffle sideways to cone C, and also touches its base, this time with their left hand. Then shuffling sideways to the right to cone D and touching the base with the right hand. They then shuffle back to cone B touching with the left hand, and run backwards to cone A. The stopwatch is stopped as they pass cone A.

Scoring:

The trial will not be counted if the subject crosses one foot in front of the other while shuffling, fails to touch the base of the cones, or fails to face forward throughout the test. Take the best time of three successful trials to the nearest 0.1 seconds.

LEG STRENGTH 1-RM TESTS (REPETITION MAXIMUM TESTS)

Purpose:

To measure maximum strength of various muscle and muscle groups.

Equipment required:

Free weights (barbells, dumbbells) or other gym equipment.

Procedure:

One repetition maximum test (1-RM leg press) is a popular method of measuring isotonic muscle strength. It is a measure of the maximal weight a subject can lift with one repetition. It is important to reach the maximum weight without prior fatiguing the muscles. After a warm up, choose a weight that is achievable. Then after a rest of at least several minutes, increase the weight and try again. The athletes chooses subsequent weights until they can only repeat one full and correct lift of that
weight.

Scoring:

The maximum weight lifted is recorded. The sequence of lifts should also be recorded as these can be used in subsequent tests to help in determining the lifts to attempt. Maximum three attempts allowed. This 1RM calculator returns predictions of 1RM based on Brzycki: 1RM = W x (36 / (37 - R)). **Matt Brzycki (2015).**

PHYSIOLOGICAL VARIABLES

VITAL CAPACITY TEST

Purpose:

Determination of vital capacity

Equipment required:

Spiro meter, Chair, and nose clips

Procedure:

Vital capacity of the subject will be determined by the Spiro meter in sitting position. The subject will be allowed to inspire the maximum amount of air voluntarily and then he will ask to blow into the dry Spiro meter to the maximum extent. While taking the test, the nose of the subject will clip using a nose clip.

Scoring:

The Vital capacity of the subject will obtain from the movement of circular volume indicator which is set a ‘0’ before the vital capacity measure will take. The result will be recorded in litter milliliter. **(Mathew, 1988).**

VO2 MAX - 12-MIN COOPER RUN/WALK TEST

Test: 12-minutes Cooper Run/walk test

Purpose: to assess aerobic power / vo2max / cardiorespiratory endurance

Equipment: running track, stopwatch, cones

Procedure: subject were instructed to run the maximum distance in 12-minutes. They were also given the option of walking if they couldn't run continuously. All subjects were motivated during the time to put their maximum effort and cover the maximum distance possible.

Scoring: the distance covered in 12-minutes was recorded in kilometers, and put in the below mentioned formula to calculate –

VO2max = (22.351 x kilometers) - 11.288

BODY FAT PERCENTAGE - SKINFOLD CALIPER

Purpose:

To estimate body fat level by the measurement of skinfold thickness

Equipment required:

Skinfold caliper (e.g., Harpenden, Slimglide, Lange), tape measure, marker pen, recording sheets. Read the Skinfold Guide for a comparison of available calipers.

Testing Procedure:

Skinfold measurement can use from 3 to 9 different standard anatomical sites around the body. The right side is usually only measured (for consistency). The tester pinches the skin at the appropriate site to raise a double layer of skin and the underlying adipose tissue, but not the muscle. The calipers are then applied 1 cm below and at right angles to the pinch, and a reading in millimeters (mm) taken two seconds later. The mean of two measurements should be taken. If the two measurements differ greatly, a third should then be done, then the median value taken.

STATISTICAL TECHNIQUE

To analyze the collected data, descriptive statistics (mean and standard deviation) will be employed to understand the data. The normality of data will be checked using Shapiro-Wilk test. Paired t-test was applied to compare the pre-test and posttest scores of each dependent

variable for all groups. Two way Mixed ANOVA will be used to compare the differences between different experimental and control group. The level of significance will be set at 0.05.

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